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**THE EFFECT ON AIRCRAFT READINESS AND SUSTAINABILITY
OF DEPOT MAINTENANCE FUNDING**

Report AF801TR1

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October 1988

Richard C. Scalzo

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THE EFFECT ON AIRCRAFT READINESS AND SUSTAINABILITY OF DEPOT MAINTENANCE FUNDING

SUMMARY

In the fall of 1987, the Air Force was faced with large cuts in Depot Purchased Equipment Maintenance (DPEM) appropriations, which support depot overhaul of airframes and engines, component repair, and other maintenance activities. Recent Program Objective Memorandum (POM) estimates of DPEM requirements have been overstated compared to actual obligations, and that overstating diminishes confidence in the requirements estimation process. Contributing to this crisis of confidence is the observation that previous cuts in DPEM funding have had no discernible effect on peacetime readiness as measured by mission capable (MC) rates. Consequently, the Air Force wishes to quantify the effects of the cuts in DPEM appropriations on peacetime readiness and on wartime sustainability. In this report, we provide preliminary information on that issue.

In the event of a shortage of serviceable spare parts, the maintenance and repair personnel of an Air Force squadron have the option of withdrawing the needed parts from its War Readiness Spares Kit (WRSK). When a part is withdrawn from the WRSK, it is used to support peacetime operations and the WRSK is not fully capable of serving its intended purpose – at least until a like part in serviceable condition is returned to it. In this case, peacetime MC rates do not decrease, but wartime sustainability does because of the withdrawal of the asset.

When DPEM appropriations are cut below the level required to maintain serviceable spares to assure desired MC rates, we expect to see more frequent withdrawals from WRSKs. The use of WRSK assets during peacetime effectively increases the peacetime operating stock (POS) asset position. In the short term, the increasing use of WRSK assets offsets the lack of money to repair enough parts to maintain peacetime MC rates, but does so at the cost of wartime sustainability. We found that while cuts in DPEM funding of between 15 percent to 20 percent may not result in a discernible change in peacetime MC rates, they may create severe problems during wartime.

BACKGROUND

An important factor influencing the cuts in DPEM funding appropriations is shown in Table 1, a listing of direct Air Force (DAF) funding and DAF obligations. DAF funding is that portion of DPEM that is used to support the day-to-day operations of the Air Force. The fact that the POM estimates, which are projected early in the program and budget cycle, have recently greatly exceeded the actual dollars obligated has raised questions about the requirements process underlying the budget estimates. The POM overestimates combined with the observation that cutting DPEM funding levels has caused no noticeable decrease in MC rates in the past, clearly indicates that the effects of such cuts on readiness *and* sustainability must be assessed.

TABLE 1

DAF REQUIREMENTS AND DAF OBLIGATIONS

PPBS ^a instrument	As of FY85 (\$ millions)	As of FY86 (\$ millions)
POM	3,917 (5/83)	4,216 (5/84)
BES ^b	4,149 (9/83)	4,091 (9/84)
President's Budget	3,915 (1/84)	3,789 (1/85)
Actual obligation	3,395 (11/85)	3,177 (11/86)

^a Planning, Programming, and Budgeting System.

^b Budget Estimate Submissions.

The Air Force has had difficulty in using quantitative tools to link dollar requirements for DPEM exchangeables (the largest part of DPEM and the most sensitive to changes in funding) to measures of readiness and sustainability for, *inter alia*, the following reasons:

- No item-by-item model has been developed to account for the complicated interaction between DPEM appropriations and the cost of depot operations.
- Long-range projections of factors used in requirements computation, especially failure rates and DPEM backlog, are difficult to calculate.
- Existing models do not incorporate many of the subtleties of repair policy, especially when changes in repair priorities occur.

Considerable time elapses between the computation of requirements and the budget execution; this time lag combined with attempts to stabilize depot charges to customers means that DPEM obligations tend to underfund the true costs of depot operations. The connection between DPEM appropriations and the manner in which these funds are disbursed is not addressed in existing models. In addition, inflation projections made several years into the future have corresponded very poorly with actual inflation rates, and a model has no way of incorporating such misjudgments.

Time lags are not the only problem in determining DPEM requirements several years into the future. In addition, DPEM requirements are inherently unstable, primarily because of the difficulty in accurately projecting failure rates for 180,000 items over a 5-year period. Our experience has shown that overestimation of failure rates for as few as 50 high-cost items can cause a significant overstatement of the dollar value of provisioning requirements, as well as that of future repair requirements. If, on the other hand, an unanticipated increase in failure rate of an item occurs, the number of repairs experienced surges and the actual repairs needed for that component are larger than the predicted requirement.

Finally, existing models do not adequately account for the resiliency of the Air Force logistics system. As funding for spare parts, maintenance, and repair become tighter, the system reacts by increasing workarounds, such as base- and depot-level cannibalization, lateral supply, working hours for base-level personnel, and the use of WRSK assets in peacetime.

This resiliency of Air Force logistics also contributes to the credibility crisis in the requirements process. It contributes to the controversy over the requirements process because people have seen DPEM funded at less than stated requirements with no corresponding decrease in the observed MC rates. The real questions, however, devolve to these

- How much of the DPEM dollar requirement is really needed?
- What level of workarounds is tolerable (especially WRSK withdrawals), for peacetime readiness and wartime sustainability?

This report describes a promising method for answering those questions.

APPROACH

When funding for spare parts for maintenance and repair becomes tight, the Air Force logistics system reacts. Since previous analyses performed with the LMI Aircraft Availability Model (AAM) have focused only on POS assets and peacetime readiness, they tended to overestimate the effects of reductions in DPEM funding by not considering the resiliency of the Air Force logistics system. Although we cannot address this resiliency comprehensively, we can consider the interplay between POS and war reserve stocks. In this analysis, we develop methods to quantify the effects of increased use of War Reserve Materiel (WRM) on peacetime readiness and wartime sustainability.

When maintenance and repair funding is reduced, the effect is felt sooner than that of a similar cut in procurement funding primarily because procurement lead-times are much longer than repair times. As the effects of the cuts are felt, a depot will be unable to repair all of the unserviceable assets returned to it from the bases, a larger fraction of POS assets will remain in an unserviceable condition and accumulate at the depots, and base POS serviceable asset levels will decrease. Thus, there will be an increased likelihood that components will fail and no serviceable POS spares will be available. The most appealing short-term solution to that problem is to use a spare from the squadron's WRSK. That solution has the immediate benefit of keeping the squadron MC rate up without incurring the problems associated with cannibalization. Using squadron WRSK assets has the apparent effect of enlarging the base's serviceable asset position. However, since the depot cannot now return enough POS assets for use, this results in a net increase in the average use of squadron WRSK assets. In case the increase in unserviceable POS assets does not exceed available WRSK assets, peacetime aircraft availability will not change. If, however, the increase in unserviceable POS assets exceeds available WRSK assets, peacetime aircraft availability will decrease. Thus, as far as peacetime operations are concerned, cuts in DPEM funding have no immediately discernible effect. In the event of war, however, squadrons will deploy with WRSKs that have been depleted to support peacetime operations and a squadron will be less able to meet its required wartime sortie schedule.

Our analysis considered a squadron of 24 F-16A aircraft and a squadron of 18 F-111D aircraft. We analyzed only items in the WRSK (by National Stock Numbers) and used logistics factors — failure rates, repair times, unit costs — from

the Air Force reparable component requirement system, D041 (Recoverable Consumption Item Requirements System). We calculated an initial POS asset position using a version of the AAM. That asset position was chosen so that when the squadron's WRSK assets were added to it, the squadron availability rate approximated the observed MC rates for the aircraft type. Since in peacetime, even when DPEM is fully funded, both POS and WRSK assets are used to support flying activity, this calibrates our squadron availability to experienced spares support levels. When only part of the repair requirement is funded, fewer base-level POS serviceables are available, and since WRSK assets are used to maintain MC rates at desired levels, the level of serviceable assets in WRSK will decline.

We considered then the effects of DPEM cuts of 20 percent, 30 percent, and 40 percent over a 2-year period. We used an item-by-item estimate of depot reparables generated (i.e., failures requiring depot repair) over the 2-year period as a surrogate for the squadron's portion of the DPEM requirement.¹ Given 100 percent DPEM funding, the depot would overhaul all of these reparables and the POS asset position would remain unchanged. With, say, 80 percent depot overhaul funding, we repaired the candidate carcasses optimally in order of improvement in (peacetime) aircraft availability per dollar of repair cost until the funding was exhausted. Those unrepaired carcasses then represented a decrease in POS assets. The total pool of assets (POS and WRSK) gives an estimate of the asset position that will be experienced during peacetime when DPEM funding is limited.

At this point, the question remaining unanswered is how many serviceable assets can be expected to remain in the squadron's WRSK? Since we expect fewer WRSK assets to be in serviceable condition, we calculated the average number of WRSK assets in use to support peacetime operations for each reparable spare in the kit for each funding level under consideration. This allowed us to compute the expected number of serviceable spares for each reparable item in the kit.

After computing the expected asset position of the WRSK after cuts in funding, we were in a position to evaluate the wartime sustainability of the kit using the Dyna-METRIC model. The sustainability associated with the various states of the

¹The DPEM requirement is computed on an aggregate, worldwide basis rather than squadron by squadron. For any given item, previously uninducted assets, nonrecurring requirements, and other special requirements can affect the overall requirement. We have adopted the one-for-one replacement requirement as a reasonably accurate simplification.

squadron's WRSK was measured by computing the cumulative expected sortie generation over a nominal 30-day scenario. The cumulative sortie generation capability associated with each state of the kit could then be compared with the planned sortie schedule.

Since we did not know how the funding cuts would be distributed across the various DPEM funding categories, and since our analysis applies only to the exchangeables portion of the DPEM appropriations, we considered three possible funding levels for the exchangeables portion of DPEM. As noted previously, the levels chosen were 60 percent, 70 percent, and 80 percent, respectively, of the full requirement.

A more detailed description of the method can be found in the appendix.

RESULTS

We examined the impacts of DPEM funding cuts for a squadron of 24 F-16A aircraft and a squadron of 18 F-111D aircraft. We used the Combat Support Management System (CSMS) kits in order to obtain a "snapshot" of onhand serviceable WRSK assets for each squadron, i.e., the starting assets (before any drawdown) reflect the onhand inventory levels of the CSMS.

The impacts of DPEM funding cuts upon sustainability are shown in Figures 1 and 2. The F-16A kit seems to be in far better shape to provide the sustainability required than that of the F-111D. In both cases, the authorized kits are able to support the planned sortie generation for both nominal scenarios, as can be seen by examining Figures 3 and 4, but again the F-111D kit seems to be more sensitive to cuts in DPEM funding. This is not surprising when we note that the F-111D is a larger and more complex aircraft and is harder to maintain than the F-16A. Consequently, one reason that the F-111D onhand kit is less able to provide sustainability is that it is drawn on more heavily than an F-16A kit during peacetime. The F-111D kit also seems more sensitive to cuts in DPEM funding.

In order to understand this phenomenon, consider the differences in the scenarios under which sustainability was evaluated (see Table 2). The planned sortie rates for the F-16A are much greater during the first 7 days of the scenario, while the sortie rates for the F-111D remain fairly constant over the duration of the scenario. The F-16A kit is essentially a Remove and Replace (RR) kit; little or no

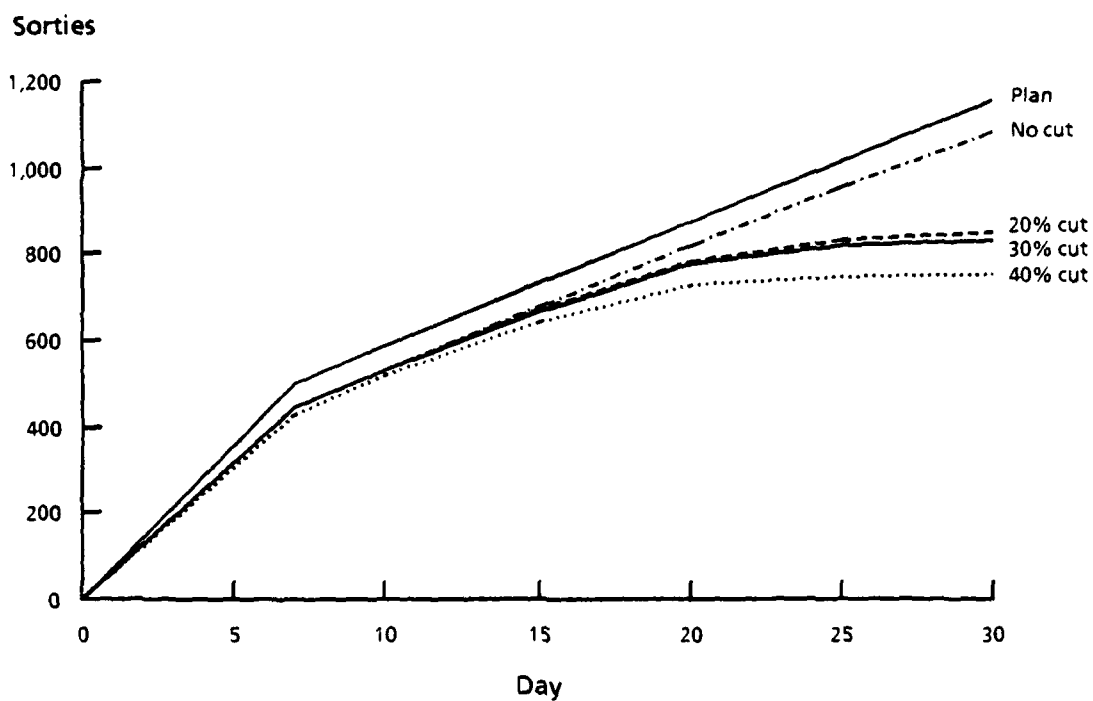


FIG. 1. CUMULATIVE SORTIE GENERATION: F-16A ONHAND KIT

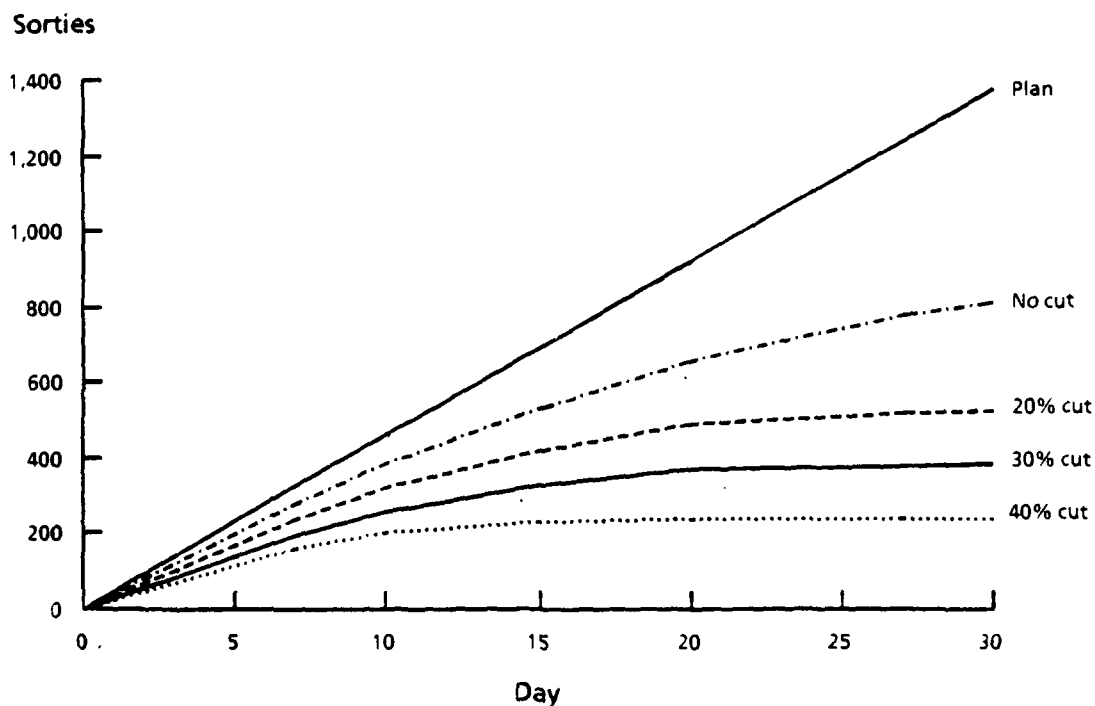


FIG. 2. CUMULATIVE SORTIE GENERATION: F-111D ONHAND KIT

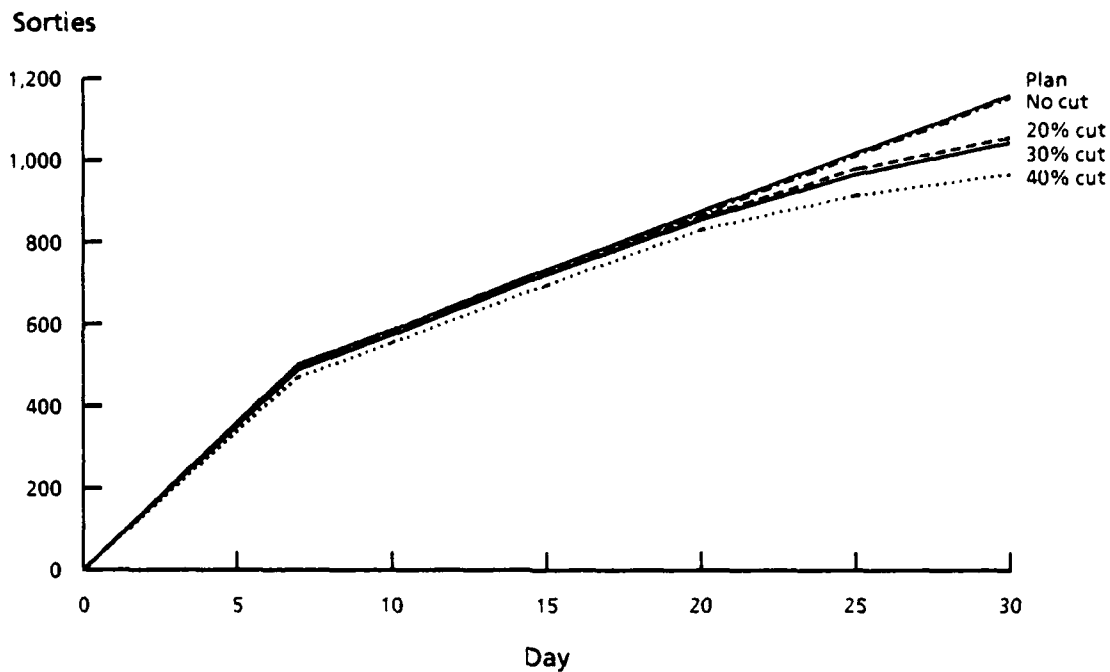


FIG. 3. CUMULATIVE SORTIE GENERATION: F-16A AUTHORIZED KIT

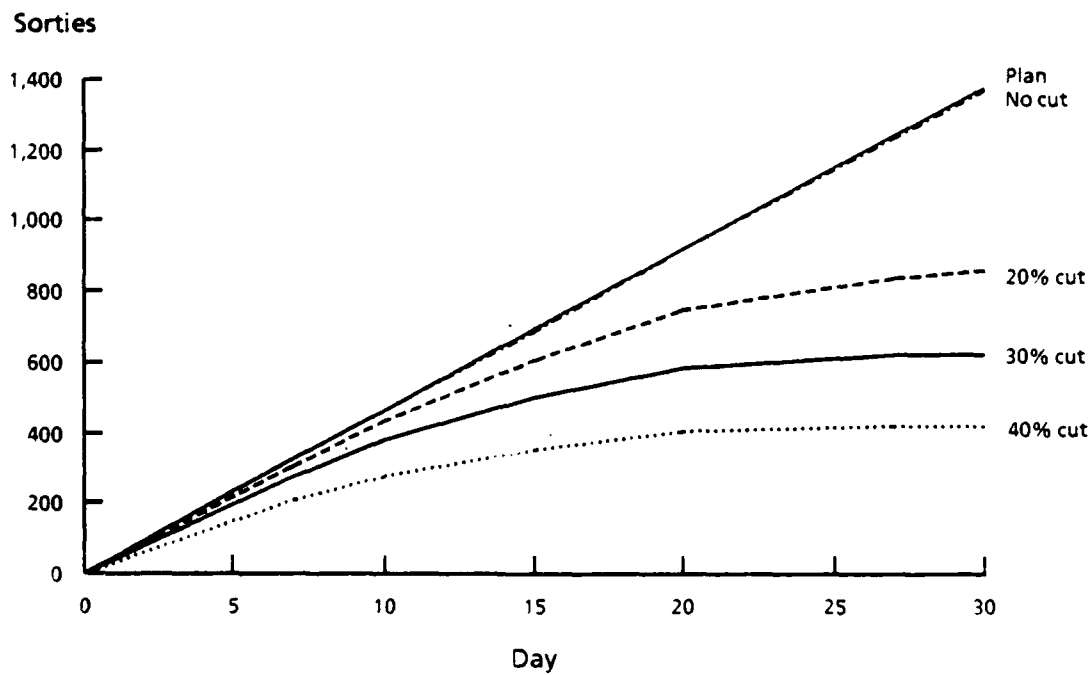


FIG. 4. CUMULATIVE SORTIE GENERATION: F-111D AUTHORIZED KIT

repair of parts is anticipated, and the effect of kit depletion are not felt until replacement parts have run out later in the scenario. On the other hand, the kit for the F-111D is essentially a Remove, Repair, and Replace (RRR) kit, relying on repair through the scenario to return failed parts to service. The lack of enough spares to cover those unserviceables in base repair will be felt almost immediately, especially early in the scenario when flying activity surges. Just how poor the current state of the F-111D kit is compared to the F-16A kit can also be seen from Table 3.

TABLE 2
REQUIRED SORTIE SCHEDULE

F-16A			F-111D		
Days	Sorties per aircraft	Total sorties per day	Days	Sorties per aircraft	Total sorties per day
1 - 7	3.00	72	1 - 7	2.60	48
8 - 19	1.20	29	8 - 27	2.54	47
20 - 30	1.16	28	28 - 30	2.48	46

TABLE 3
VALUE OF DEPLETED WRSKs

WRSK assets	F-16A (\$ millions)	F-111D (\$ millions)
No cut		
Authorized WRSK	22.0	113.5
CSMS onhand	18.3	58.7
20% DPEM cut	11.8	38.5
30% DPEM cut	10.9	31.4
40% DPEM cut	9.7	15.8

A summary of the effects of the selected DPEM cuts on both peacetime aircraft availability and wartime sustainability is shown in Tables 4 through 7. The F-16A kit seems more robust even when used to support peacetime operations. An examination of Table 8 shows that the dollar value of the POS required to support

the F-16A is a much greater fraction of the cost of the authorized WRSK than for the F-111D. Moreover, the dollar value of the POS for the F-16A is also a much larger fraction of the onhand WRSK than for the F-111D. Thus, the F-16A kit seems to be more complete and less susceptible to peacetime withdrawals than the F-111D kit.

TABLE 4
READINESS AND SUSTAINABILITY IMPACTS: CSMS ONHAND KITS
(F-16A results)

Exchangeables dollars	Peacetime aircraft availability rates	Expected sorties over 30 days	Percent requirement	Sorties lost
No cut	0.93	1,086	94	-
20% cut	0.93	850	74	236
30% cut	0.78	834	72	252
40% cut	0.47	756	65	330
Total sortie requirement: 1,160				

TABLE 5
READINESS AND SUSTAINABILITY IMPACTS: CSMS ONHAND KITS
(F-111D results)

Exchangeables dollars	Peacetime aircraft availability rates	Expected sorties over 30 days	Percent requirement	Sorties lost
No cut	0.91	810	59	-
20% cut ^a	0.83	523	38	287
30% cut	0.24	382	28	428
40% cut	0.00	240	17	570
Total sortie requirement: 1,375				

^a A 14 percent cut in DPEM exchangeables was the maximum cut that allowed maintenance of 91 percent peacetime rate.

TABLE 6
READINESS AND SUSTAINABILITY IMPACTS: CSMS AUTHORIZED KITS
(F-16A results)

Exchangeables dollars	Peacetime aircraft availability rates	Expected sorties over 30 days	Percent requirement	Sorties lost
No cut	0.96	1,153	99	-
20% cut	0.96	1,061	92	92
30% cut	0.82	1,044	90	109
40% cut	0.56	968	84	185
Total sortie requirement: 1,156				

TABLE 7
READINESS AND SUSTAINABILITY IMPACTS: CSMS AUTHORIZED KITS
(F-111D results)

Exchangeables dollars	Peacetime aircraft availability rates	Expected sorties over 30 days	Percent requirement	Sorties lost
No cut	0.99	1,369	99	-
20% cut	0.99	862	63	507
30% cut	0.86	625	45	744
40% cut	0.14	419	30	950
Total sortie requirement: 1,376				

TABLE 8
VALUE OF ASSETS

Assets	F-16A (\$ millions)	F-111D (\$ millions)
Authorized WRSK	22.0	113.5
WRSK onhand	18.3	58.7
POS assets	9.7	88.5

CONCLUSIONS

Each onhand kit is a "snapshot" of the WRSK assets of a given squadron on a given day and so may not be representative of the expected (or time average) content of the kits. Clearly a sample of two CSMS onhand WRSKs is not large enough to allow us to draw any firm conclusions. However, we believe that the results almost surely bound the problem, with the F-111D providing a worst case. Moreover, we have demonstrated a mechanism whose effects puzzle many observers. Namely, why is it that when DPEM funding is cut, MC rates do not drop discernibly. Part of the answer to that question is that MC rates are being maintained by the peacetime use of WRM, and the cost to wartime sustainability goes largely unnoticed. The resulting diminished capability during wartime is, nonetheless, a real cost.

FUTURE DIRECTIONS

The method developed for this study can also be applied to Air Force-wide computations. The advantage of adapting this method Air Force-wide is that it offers a broader view of the implications of DPEM cuts during peacetime. By using WRSK data from the D029 WRSK/BLSS² Computation System, we also may be able to examine the effects of DPEM cuts during wartime on a broader scale than was possible on a squadron-by-squadron basis. But more important, the results of this report point to the need to integrate the POS and WRM requirements computation. Given the difficulty of that task, however, it must remain a long-term goal. We believe that some of the techniques developed to solve sustainability requirements problems will eventually prove useful in the development of an integrated requirements computation. We also believe that the further development and refinement of the method presented in this report will serve as an interim method for assessing the impact of changes in DPEM exchangeables funding.

² BLSS = Base Level Self-Sufficiency.

APPENDIX

METHODOLOGY

The method used to estimate the effects of Depot Purchased Equipment Maintenance (DPEM) funding levels on the readiness and sustainability of aircraft involves the iterative use of a version of the Aircraft Availability Model (AAM). The method will be described as an algorithm.

- *Phase I* – Estimate the starting peacetime operating stock (POS) asset position through the following steps:
 1. Use the AAM to optimally procure spares to a given target for squadron availability, $A_n(s)$. Denote this asset position by $s = (s_1, \dots, s_n)$, where n is the number of parts under consideration, and s_i is the spares level for component i .
 2. Add the War Readiness Spares Kit (WRSK) assets to initial peacetime asset position and evaluate the availability, $A_n(s+w)$, where $w = (w_1, \dots, w_n)$ is the WRSK asset position.
 3. Stop if $A_n(s+w)$ is close enough to 1 – NMCS (not mission capable supply) for the aircraft type that makes up the squadron's planes; otherwise, go to Step 1 and adjust the targeted A_n and have the model compute a new s and repeat Steps 2 and 3.
- *Phase II* – Estimate the asset position of the squadron WRSK after 2 years of cuts in repair funds through the following steps:
 1. Delete 2 years of depot returns (used to approximate repair requirements), $r = (r_1, \dots, r_n)$, from $s+w$ to get an initial asset position for repair: $s+w-r$. Let R denote the dollar value of these repairs.
 2. Use the model to optimally "repair" parts, beginning from $s+w-r$, until a given fraction of R is spent, say, $f \cdot R$. Denote this new asset position as $t = s+w-r + R(f \cdot R)$, where $R(f \cdot R)$ is the "repair" list from the model.
 3. Since the model does not distinguish between POS and WRSK assets, compute the expected distribution of parts among POS and WRSK by calculating the expected drain from the WRSK for each item. To do this, we assume that for each Item i , $t_i = w_i + s_i'$. That is, we assume that the kit at any time is full but that the peacetime assets have been decremented by $R(f \cdot R) - r \leq 0$, and we compute the average number of

parts missing when the POS is $s_i' = \max[0, t - w]$. Denote the depleted WRSK asset position by w' . The average number of missing WRSK parts of Type i is given by:

$$EBO(s_i') - EBO(t_i),$$

where $EBO(s_i)$ denotes the expected backorders given asset level s_i .

- *Phase III* – Evaluate the sustainability of the WRSK when the asset position, s , is given by w' from Step 3 of Phase II.

The following important assumptions are inherent in this approach:

- WRSK assets will be used freely to support peacetime availability.
- The only extra stock that supports peacetime availability is contained in the squadron's WRSK.
- Stock levels, once determined, remain constant over the period in question, i.e., no stock condemned.
- The initial asset position is determined by the model, which means it is an optimal procurement policy and all of the sensitivities associated with optimal policies.
- Funding for procurement of spares does not change.
- The flying-hour program does not change over the periods of the computation.
- Only stock in the WRSK is considered in the calculation of A_n .

The following three assumptions are inherent in the version of the Demonstration Aircraft Availability Model (DAAM) used in the analysis.

- At most, two levels of indenture exist.
- No common components.
- QPA (Quantity Per Application) = 1.

This process differs from a standard run of the procurement-repair version of the AAM in the following manner.

The AAM is a procurement-repair model, which means that it solves the procurement-repair problem:

Problem I

$$\max A_n(s_0, w_0, r, s)$$

$$\text{s.t.} \quad \sum_{i=n}^{n_p} c_i s_i \leq C,$$

$$\sum_{i=1}^{n_r} c_i^* r_i \leq R,$$

$$r_i \leq R_i.$$

The method outlined above involves the solution of a pair of problems, where:

s_0 is an initial POS asset position.

w_0 is an initial War Reserve Materiel (WRM) asset position.

r is the vector of assets repaired.

s is the vector of assets procured.

c_i is the procurement cost of a spare of Type i .

c_i^* is the repair cost of a spare of Type i .

C is a dollar constraint on POS procurement.

R is a dollar constraint on repair.

R_i is the maximum number of repairs that can be made for Item i .

n_p is the number of National Stock Numbers (NSNs) procured.

n_r is the number of NSNs repaired.

The procurement-repair version of the AAM solves this problem by means of marginal analysis, which means that parts are procured or repaired, starting from an initial asset position, s_0 , up to an asset position, $s_0 + r + s$. Since any given part, i , is cheaper to repair than to buy, the model repairs up to R_i before making any buys (unless the dollar constraint, R , is breached). When the model is run with the WRM option on, WRM onhand assets and onorder assets are added to the initial asset position for the computation.

Problem II

$$\begin{aligned} \min \quad & \sum_{i=1}^{n_p} c_i s_i \\ \text{s.t.} \quad & A_n(s_o, s) \geq A, \end{aligned}$$

and

$$\begin{aligned} \max \quad & A_n(r_o, s_o, w_o, r) \\ \text{s.t.} \quad & \sum_{i=1}^{n_r} c_i^* r_i \leq R, \end{aligned}$$

where s_o , w_o , s , r , c_i^* , and R have the same meaning as in Problem I. For Problem II, A is a target availability for procurement. Note that Problem II consists of a pair of optimization problems. The first is only solved in order to obtain an initial asset position for the second and is an optimization of a purely procurement process. The second is an optimization of a purely repair process. Both optimizations associated with Problem II are accomplished by means of marginal analysis.

Earlier in our investigation of DPEM funding, we found that Problem I leads to results that were exquisitely sensitive to DPEM funding levels. The method used solves Problem II, and results proved to be less sensitive to DPEM funding levels. In fact, the peacetime results were not sensitive at all to small cuts in DPEM funding levels.

Two reasons that possibly account for this difference in sensitivity immediately come to mind. The first is that Problem I yields an optimal solution to the procurement-repair problem, while Problem II yields a suboptimal solution to the problem. Optimal solutions for the procurement-repair problem are more sensitive to changes in funding than suboptimal solutions. The second reason is that, when Problem I is solved, some NSNs are not associated with the WRM buffer in peacetime for such parts. The question remains as to which effect is dominant.